

Engineering and Economic Evaluation Perspective in the Production of NiO Nanoparticles

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ABSTRACT

Nickel oxide (NiO) nanoparticles have been proven and can be used in a variety of important applications. The purpose of this research was to evaluate the production process of NiO nanoparticles using the industrial co-precipitation method in terms of engineering and economic evaluation. Specifically, research was conducted by varying raw materials, product selling prices (GPM), equipment prices, and number of employees, which are compared with several economic parameters such as total investment cost (TIC), gross profit margin (GPM), break even point (BEP), payback period (PBP), net present value (NPV), and cumulative net present value (CNPV). The results showed that the PBP analysis showed that the investment would be profitable after more than 4 years with minimum product sales (GPM) of at least 90% and an increase in the price of raw materials no more than 15% of the ideal price. From this economic evaluation analysis, we can conclude that this project is feasible to run.

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1. Introduction

Nowadays, nanomaterials are widely applied in various fields. One example of nanomaterials that are currently widely used is nickel oxide nanoparticles (NiO). These nanomaterials show many unique optical, electrical, magnetic and chemical properties [1]. NiO can be used in important applications such as catalysts, gas sensors, magnetic materials, electro chromic films, battery cathodes, and super capacitors [2-4].

Several methods have been developed by researchers for the synthesis of nickel oxide nanoparticles. Examples are the co-precipitation method [5], the sol-gel method [6], the green method [7], the reaction between nickel chloride and hydrazine [8], low pressure spray pyrolysis [9], the surfactant mediated method [10], the process simple liquid phase [11], complexation precipitation method [12] and other techniques [13-15]. Of the various methods, the co-precipitation method is the best method for producing NiO nanoparticles on an industrial scale. This method is easy to use because the raw materials used are easily available and inexpensive.

In this study, we did research the industrial production process of NiO nanoparticles in terms of engineering and economic evaluation. The synthesis of existing NiO nanoparticles is only discussed for laboratory scale production. There is no information about economic evaluation on the industrial scale of NiO nanoparticles. Economic evaluation is very important because it is related to further studies to increase production. Economic evaluation of the chemical industry is a form of quantitative assessment of what is expected and desired by the community to carry out the investment process in a project [16]. To get a feasibility study, the data is calculated to get the maximum results of NiO fabrication that can be applied on an industrial scale. In addition, this research is important to help in making a decision whether the fabrication of NiO nanoparticles is profitable or not. Also, this study can be used to suggest ways to optimize projects and to benefit

economic growth. We do economic variation on several factors that influence the scale of the NiO nanoparticles industry production.

2. Method

2.1. Energy and Mass Balance Analysis

To calculate energy and mass balance based on Figure 1 showing the process of producing NiO nanoparticles on an industrial scale, the synthesis of these nanoparticles requires several assumptions:

- (i). The process is carried out based on the co-precipitation method,
- (ii). Using technical $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$,
- (iii). Using technical NaOH,
- (iv). Water is obtained from river water which is treated using water treatment,
- (v). Comparison of materials used in the production of NiO nanoparticles is estimated based on stoichiometric calculations,
- (vi). The screening process is going well,
- (vii). Production process for 13 hours in 1 day,
- (viii). The mass of NiO nanoparticles is reduced by 5% during the production process transfer.

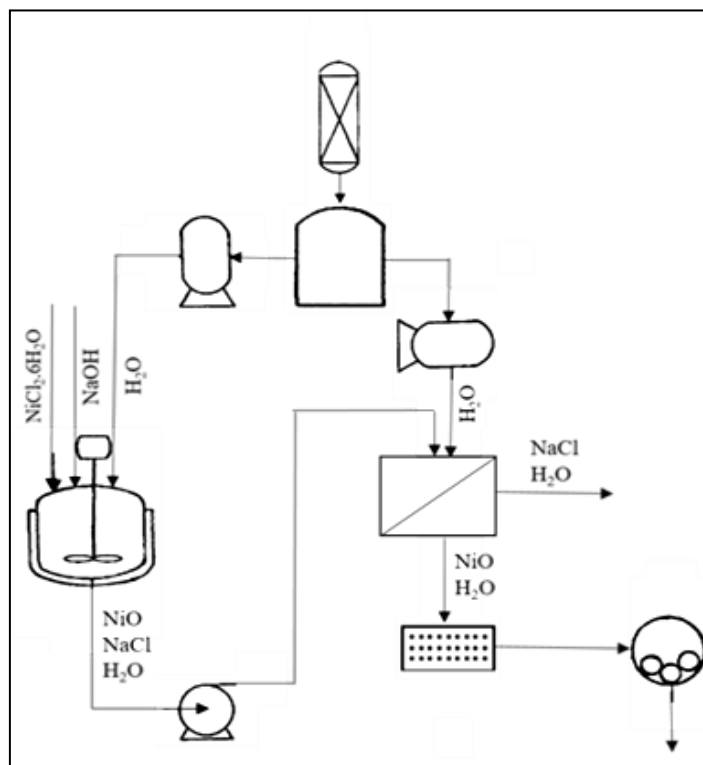


Fig 1. Scheme of the process of making NiO nanoparticles by the co-precipitation method

2.2. Economic Evaluation

In this research, the method that has been used is based on the analysis of prices of raw materials and equipment sourced from the available online web. We have analyzed the feasibility study on manufacturing NiO nanoparticles on an industrial scale. This feasibility study is based on simple mathematical calculations using Microsoft Excel to obtain several economic evaluation parameters; total investment cost (TIC), gross profit margin (GPM), break-even point (BEP), return period (PBP), net present value (NPV), and cumulative net present value (CNPV). Calculation of this parameter is based on the formula:

- (i). TIC is the cost to build a factory and the initial costs (equipment costs and equipment related services for equipment installation at the factory) [17],
- (ii). GPM is an estimate by subtracting the cost of products sold with the cost of raw materials [18],
- (iii). Calculates BEP by dividing fixed costs and profits,
- (iv). PBP is calculated based on when CNPV reaches zero for the first time,
- (v). NPV is the value obtained from a project that states expenditure and income by considering the opportunity cost of social capital (as discount rate i) [19],
- (vi). CNPV is the calculation of the total NPV value from the beginning of the factory construction to the end of the factory operation. In short, CNPV can be obtained from the amount of cumulative financial flows each year,

$$\text{CNPV} = \sum \text{NPV} \quad (1)$$

Economic evaluation calculations can be obtained with the following assumptions:

- (i). Production site already exists (not rent),
- (ii). This project runs for 20 years,
- (iii). 10% entrance tax,
- (iv). 1 USD is equivalent to 14,172 IDR [20],
- (v). Wages of 1 employee per year 3723.44 USD,
- (vi). 1 year is equivalent to 300 days
- (vii). 1 kWh is equivalent to 0.10 USD

Then we have made several variations in changes in raw materials, product selling prices (GPM), equipment prices, and the number of employees.

3. Results and Discussion

3.1. Engineering Perspective

In this case, all the chemical compositions in the reaction have been increased up to 50,000 times based on literature [3] on the production of NiO nanoparticles. The increase was made to produce NiO nanoparticles on an industrial scale. The raw materials used in this production are listed in Table 1. After upgrading the project, we have assumed the transfer from one tool to another in the process of making nano NiO particle products has 5% shrinkage so that this reaction produces 471.55625 kg per day and rounded up to 471 kg per day a day.

Table 1. Raw materials used

NiCl ₂ .6H ₂ O (kg)	H ₂ O (L)	NaOH (kg)
297.06	12.500	1.065

The tools used in the production of NiO nanoparticles are reactors with 1.000 L capacity, pumps, water treatment, tanks, filtration, ovens, and grinding. Figure 1 shows the process of producing NiO nanoparticles on an industrial scale. All raw materials are loaded and reacted in the reactor. Water is obtained from rivers that are treated using water treatment. Then the reaction results are separated using a filtration to produce residues and filtrate. The residue is taken and dried in the oven. To produce NiO nanoparticles, a grinding tool is used to produce nanoparticles products [21].

3.2. Economic Evaluation

1) Ideal Conditions

Figure 2 shows a graph of the ideal conditions of the relationship between CNPV/Investment on the y axis and life time (year) on the x axis. The graph was obtained from the final evaluation results in the form of a CNPV graph. The curve shows a decrease in CNPV/Investments in the first to second years. Then, there was an increase in the 3rd to 20th years. This project takes 4 years to reach the payback period (PBP) point.

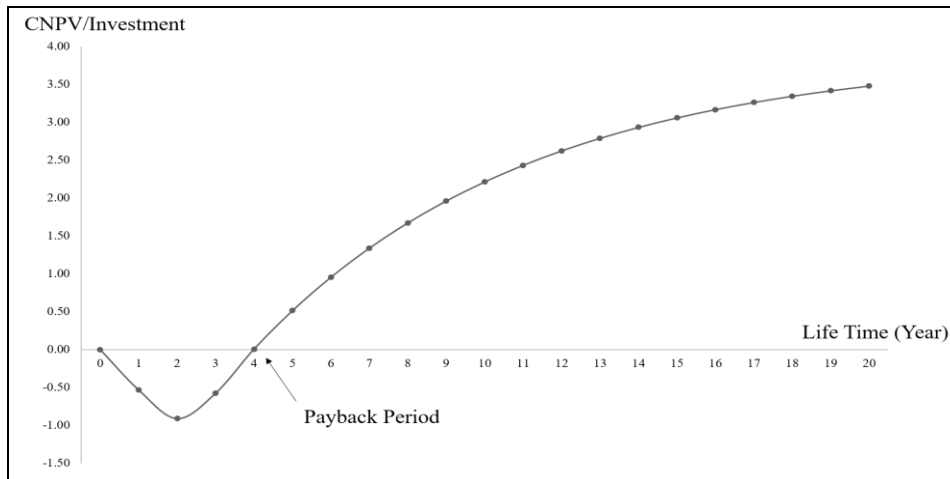


Fig 2. Ideal condition for CNPV/Investment to life time (Year)

By calculating the length of the project for 20 years, the results obtained show a decrease in the graph in years 0 to 2 decreased due to project needs. Even so, the project experienced an increase in the 3rd year and beyond. PBP analysis shows that the investment be profitable after more than 4 years. This project takes not too long to get back the initial investment. Thus, the production of NiO nanoparticles on an industrial scale is profitable [22].

2) Variation in Changes in Prices of Raw Materials

Figure 3 shows changes in raw materials prices in the manufacture of NiO nanoparticles on an industrial scale. The graph explains the relationship between CNPV/Investment on the y axis and life time (year) on the x axis. The graph is obtained based on the results of variations in raw materials. This variation is done in 5 conditions with a difference of 5%; 95%, 100% (ideal conditions), 105%, 110% and 115%. In the first condition (RM 95%), it shows a good change because the line is above the ideal curve. If there is a price increase as in the line below the ideal conditions line, the change has a significant difference.

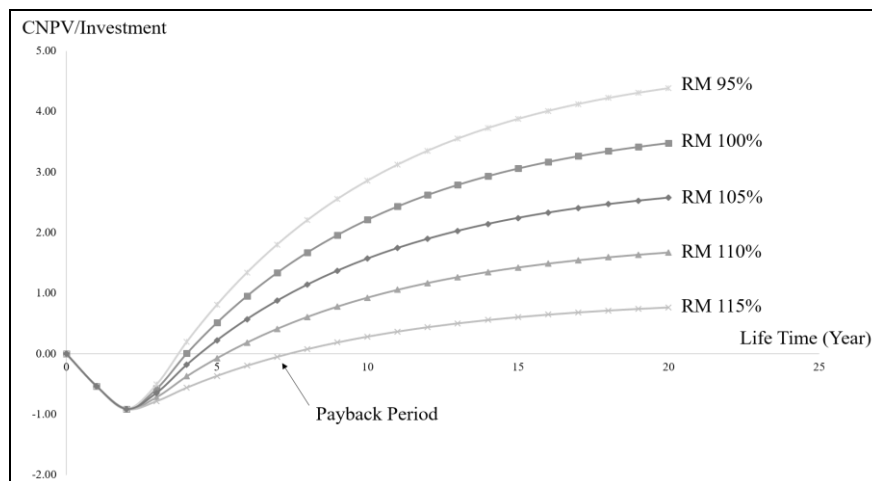


Fig 3. The curve of CNPV under various condition raw materials

In the condition of raw materials 95%, this condition can occur due to a decrease in the price of raw materials than the price of raw materials ideally. It can also increase the price of raw materials (105%, 110%, and 115%). Can be seen from the graph, the increase in raw materials prices up to 115% is less than ideal, this is because PBP shows in the 8th year. Therefore, an increase in the price of raw materials has a negative effect on the project [23].

3) Variations in GPM changes

Figure 4 shows the variation in selling price changes (GPM). The graph shows the relationship between CNPV / Investment on the y axis and Life Time (Year) on the x axis. The graph is obtained from the results of 5 variations that we did. A difference of 5%; 110%, 105%, 100% (ideal

conditions), 95%, and 90%. Two lines above the ideal conditions line, indicate more favorable conditions. However, the selling price is more expensive than the ideal effect on market sales. As well as two lines below the ideal conditions line indicates a decrease in CNPV/Investments and this is less than ideal. Can be seen on the graph, PBP on the 90% GPM line shows in the 7th year. Companies that maintain high selling prices can increase the company's net profit and vice versa. In this case, any changes in selling prices can affect the company's net profit [24]. Thus, a larger GPM means to generate greater profits compared to a small GPM if measured in the same sales value.

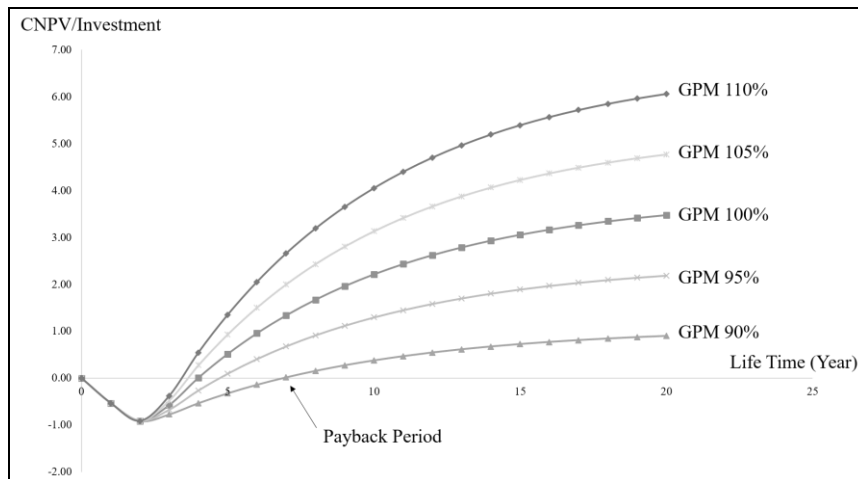


Fig 4. The curve of CNPV under various condition GPM

In the variation of the selling price (GPM), the selling price of NiO nanoparticles less than 90% is less recommended. This is because PBP analysis shows that investment can be profitable after more than 7 years which makes this project less attractive to industrial investors. The unattractive condition is because investors took profits too long. From the results of the payback analysis this period can be chosen with a shorter payback period. Where, the payback period can be interpreted as a period that is needed to be able to recoup investment expenditure by using proceeds or net cash flows [25]. In order to get a shorter return on investment, a smaller PBP value is chosen.

4) Variations in Equipment Price Changes

Figure 5 shows a graph of changes in equipment prices. This change was made fewer than 5 conditions, namely 100%, 110%, 120%, 130%, and 140%. The relationship contained in the graph is between CNPV/Investment on the y axis to life time (year) on the x axis. From this graph, changes in equipment prices do not significantly influence changes in CNPV/Investment. However, changes in equipment prices must be considered because they can affect the initial year of the NiO nanoparticles project. At a 140% change in equipment prices, PBP value in the 5th year, PBP values with ideal conditions differ by 1 year.

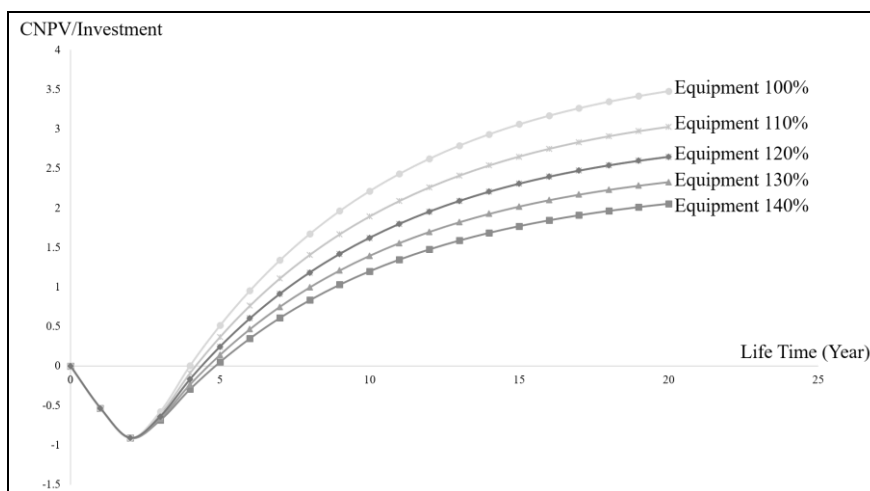


Fig 5. The curve of CNPV under various condition equipment

5) Variation of Change in Number of Employees

Figure 6 shows the change in the number of employees in the NiO nanoparticles production industry. The graph explains the relationship between CNPV/Investment on the y axis and life time (year) on the x axis. The graph is obtained based on the results of variations in the number of employees' changes in 5 conditions. Each condition has a difference in the number of 4 employees. Changes in the number of employees are not too significant.

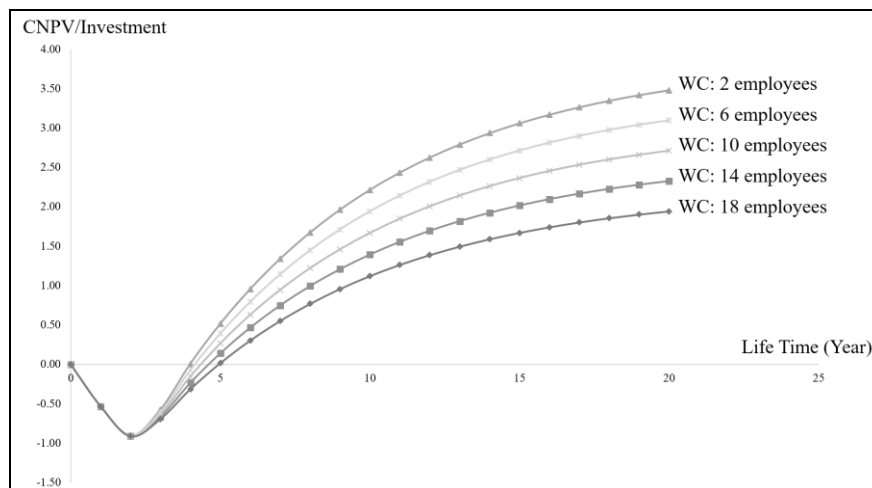


Fig 6. The curve of CNPV under various condition working capital

The number of employees in this industry does not significantly influence. However, on the change in the number of employees as many as 18 employees, PBP value shows in the 7th year. That year is still a promising investment. If the output value of an industrial company increases, producers tend to increase their production capacity. Therefore, it takes a lot of employment to increase the amount of production of a company or industry. Thus, it can affect the expansion of employment [26].

4. Conclusion

This study shows an engineering perspective and economic evaluation in industrial scale production of NiO nanoparticles. The production of NiO nanoparticles is based on the co-precipitation method, because this method is easy and inexpensive. PBP analysis shows that investment can be profitable after more than 4 years. It could be that this project can compete with capital market standards because the investment can return in a short time. Minimum product sales (GPM) of at least 90% and an increase in the price of raw materials no more than 15% of the ideal price. From this economic evaluation analysis, we can conclude that this project is feasible to run.

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